STUDIES THE EFFICACY OF PLANT GROWTH PROMOTING RHIZOBACTERIA ON TOMATO (*Solanum lycopersicum*) GROWING IN LOWER WESTERN HIMALAYAN ZONE OF HIMACHAL PRADESH

SYNOPSIS

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Under the supervision of
Dr. Vijay Kumar
Assistant Professor

DIVISION OF MICROBIOLOGY
DEPARTMENT OF PHARMACEUTICAL AND HEALTH SCIENCES
SCHOOL OF PHARMACEUTICAL AND HEALTH SCIENCES
CAREER POINT UNIVERSITY HAMIRPUR
TIKKER (KHARWARIAN), BHORANJ
HAMIRPUR (H.P.)-176041, INDIA

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Introduction

Tomato (*Solanum lycopersicum*) belongs to the genus Lycopersicon under Solanaceae family. Tomato is originated in Peru of South America and name of crop came from the Aztec word "Tomato". Common names for the tomato are: tomate (Spain, France), tomat (In-donesia), faan ke'e (China), tomati (West Africa), tomatl (Nahuatl), jitomate (Mexico), pomodoro (Italy), nyanya (Swahili) (Bauchet & Causse, 2012). India is in second largest producer of production of tomatoes in the world only behind China. As per the data provided by the Statista Research Department, India produces 21 million metric tons of tomatoes in 2021. World tomato production was 38.54 million tons in 2020, an increase of 3.1 % from 37.38 tons in 2019. The major tomato producing states in India are Andhra Pradesh, Madhya Pradesh, Karnataka, Gujarat, Odisha, West Bengal, Chhattisgarh, Bihar, Telangana, Tamil Nadu, Uttar Pradesh, Maharashtra, Haryana, and Himachal Pradesh. These states are account for about 90 % of the total production of the country. Tomato is the world's largest vegetable crop and known as protective food both because of its special nutritive value and also because of its widespread production (Gatahi, 2020). They are rich in minerals, vitamins, essential amino acids, sugars, and dietary fibers. Tomato contains much vitamin B and C, iron, folate, magnesium, potassium, choline, and phosphorus. The attractive red color of fruit is due to lycopene and yellow color is due to carotenes (Khoo et al., 2011). It is an important source of vitamins and an important cash crop for small-holders and medium-scale commercial farmers. As it is short duration crop and gives high yield, it is important from economic point of view and hence area under its cultivation is increasing day by day (Gatahi, 2020).

Fertilizers, either chemical or organic, can help provide the extra nutrients that tomatoes need to grow quickly (Burnett, Mattson & Williams, 2016). Chemical fertilizers are compounds which encompass the large nutrient concentration needed for growth of plant. In other words, these are man-made materials that supply the required nutrients to plants (Pahalvi et al., 2021). The prolonged use of chemical fertilizer has declined the agricultural soil quality with the reduction in soil organic matter (SOM) content, and even an increase in environment pollution and soil acidity that has become a serious concern (Bhatt, Labanya & Joshi, 2019). Chemical fertilizers are detrimental to agriculture as salt is one of its major contents, which is detrimental for plants and soil. From the last decades, PGPR have gained interest in research because of stimulation of plant growth, increasing crop

yields, being less harmful to the environment and also reducing the cost of chemical fertilizer (Kundan et al., 2015).

The word PGPR was coined by Kloepper and Schroth in 1978 (Pande & Bisht, 2019). The term "plant growth promoting bacteria" refers to bacteria that colonize the roots of plants that enhance plant growth by a wide variety of mechanism like phosphate solubilization, siderophore production, and biological nitrogen fixation (Hayat, Ahmed & Sheirdil, 2012). Hiltner firstly introduced the concept of Rhizosphere to describe the narrow zone of soil surrounding the root where microbe populations are stimulated by root activities is also known as "Rhizosphere effect". Rhizosphere is that the great source of microbes and microbial activity and thus better mentioned to as "store house of microbes" (Philippot et al., 2013). The working mechanism of PGPR can also be separated into direct and indirect method. The direct mechanisms of PGPR are biofertilization, stimulation of root growth, rhizoremediation, and plant stress control. On the other hand, rhizobacteria involved indirectly is by reducing the impact of diseases and induced systematic resistance (Lugtenberg & Kamilova, 2009).

The common genera that involved in PGPR are *Bacillus*, and *Azospirillum* (Hayat, Ahmed & Sheirdil, 2012). The soil microorganisms used in biofertilizer are phosphate solubilizing microbes, *Azospirilum* sp, *Azotobacter* sp, *Rhizobium* sp, *Nitrosomonas* sp, *Nitrobacter* sp, and *Azotolla* sp (Ibiene et al., 2012). Indigenic bacteria from the genus *Azotobacter, Acinetobacter*, *Azospilium*, *Bacillus* and *Pseudomonas* are types of microorganisms found in soil and plants, especially at the base of the stems and roots (Hayat et al., 2010). These four genera of bacteria have been widely used as Plant Growth Promoting Rhizobacteria (PGPR) to increase plant growth through nitrogen fixation, phosphate dissolving, and phytohormone production and to reduce the intensity of disease attacks caused by soil pathogens (Noumavo et al., 2016). In addition, the use of biological fertilizer as a biofertilizer that are significantly helping plants to provide nutrients for plant growth, control pathogens in plants and reduce the amount of synthetic fertilizer applied to the crops (Itelima et al., 2018). Exploration of potential microorganisms in stimulating plant growth from plant tissues and rhizosphere is one of the technologies developed at this time. Soil fertilizing microbes when applied on the seed (Nihorimbere et al., 2011), plant surface or soil which can improve the efficiency of fertilization, soil fertility, and soil quality (Nihorimbere et al., 2011). This indicates that the environmental conditions play important roles in nutrient supply through N tethering, phosphate dissolving, and production of

phytohormones as well as producing enzymes to suppress plant pathogens and disease (Kalay et al., 2021). Therefore, it's necessary to seek out and develop root-colonizing bacteria or potential rhizobacteria for plant fertilizers (Khan et al., 2009).

The use of microbial inoculants as a biofertilizer increase crop yield, eco-friendly and can be utilized as an alternative or to reduce the usage of chemical fertilizer (Nosheen, Ajmal & Song, 2021) and will ultimately benefit the farmers. Formulation should contain ingredients (cocopeat powder, mustard husk, chinaberry leaf powder, press mud-based bioformulation) in a suitable carrier with additives that will help in the stabilization and perform as protective shield of the bacterial cell during storage (Yahya et al., 2021). A major purpose of bacterial inoculant formulation is to provide suitable microhabitat for survival in the soil ecosystem (Arora, Khare & Maheshwari, 2010). Application of PGPB as inoculants have shown positive results in increasing grain yield of different crops such as wheat, maize etc. (Di Benedetto et al., 2017). This is one of the promising approaches to replacing chemical fertilizers, pesticides, fungicides, and antibiotics while also developing stable PGPR for better agriculture and long-term sustainability (Gupta, et al., 2015).

This study aims to isolate plant growth promoting rhizobacteria from tomato rhizosphere as they are potentially used as biocontrol, bio-stimulant and biofertilizer. The present investigation is carried out to isolate the native isolates from rhizospheric soil of tomato plant from different locations of Solan district (Kandaghat, Basal, Nauni, and Jaunaji) of Himachal Pradesh. These bacteria will be characterized and screened in vitro for various PGP attributes. Furthermore, to evaluate the efficiency of selected strains of PGPR in growth promotion and biocontrol activity of tomato under net house condition. Field experiment will be conducted to further confirm the efficacy of selected bacterial isolates to improve growth and yield of tomato under certain environmental conditions.

Literature Review

Ibiene et al. (2012) they examined the effect of PGPR on *Lycoperscium esculentus*. They also identified *Azotobacter* species, *Nitrobacter* species, and *Nitrosomonas* species. They were tested in-*vitro* ability of PGPR to produce phytohormones (siderophore, phosphate solubilization and indole acetic acid).

Pande & Kulkarni (2015) isolated 50 bacterial isolates from Wheat rhizospheric soil samples. In his study, it was found that only 6 strains showed all the traits of plant growth promotion. This study reviled that, all the isolates exhibited production of indole acetic acid, Gibberellic acid, indole-3 butyric acid, siderophore, ammonia, HCN, and solubilized inorganic phosphate.

Arora et al. (2014) determines 5 different carrier material potential for survival of PGPR (*Rhizobium, Pseudomonas* strains) isolates from *Trigonella foenum Graecum.*

Chakraborty et al. (2014) they characterized and isolated bacterial strains & evaluate the effect of these strains on plant growth promoting traits by determining the P- solubilization efficiency, IAA production, HCN production and siderophore production.

Geetha et al. (2014) isolated 140 bacteria from plant rhizosphere soil. Out of which 6 strains was selected for further studies based on various morphological, biochemical, and physiological methods which can be used as biofertilizers as well as biocontrol agents.

Apastambh et al. (2016) isolated 8 strains of fluorescent *Pseudomonas* and 4 strains of *Bacillus* from Banana rhizosphere of Nanded, Maharashtra. These strains were characterized morphologically and biochemically and studied for their plant growth promoting activities such as GA production, phosphate solubilization and IAA production. These strains were tested for antifungal activity against plant pathogen.

Islam et al. (2016) isolated 66 bacterial isolates, out of 66 only 10 bacterial isolates (*Pseudomonas stutzeri, Bacillus subtilis, Stenotrophomonas maltophilia,* and *Bacillus amyloliquefaciens*) were selected based on their *in vitro* plant growth promoting attributes and antagonism of phytopathogens from cucumber rhizospheric soil sample, Gazipur, Bangladesh. These bacterial isolates produced high level of IAA (26.78 - 51.28 μg mL^{-1}), acetylene reduction activities (1.79 - 4.9 μmole C_2H_4 mg^{-1} protein h^{-1}) were observed in eight isolates.

Tiwari et al. (2016) isolated nine bacteria from pigeonpea rhizospheric soil samples from different areas of Bijarkala and Kumarganj. This investigation was carried out to isolate, screen and characterized for various plant growth promoting activities. In his study, it was found that six isolate produced indole-3-acetic acid in the range of 56 to 97 μg/ml, single isolate producing p-solubilization activity in Pikovskayas agar, and six isolate were found to be positive for siderophore production and also showed antifungal activity against

Fusarium. Out of nine isolates, seven isolates were exhibited *in vitro* plant growth promotion activities and indicated that these isolates may be exploited as biofertilizers and microbial inoculants for pigeonpea crop.

Singh & Lal (2016) isolated 72 rhizobacterial belonging to genera *Bacillus, Pseudomonas,* and *Rhizobium* from Wheat rhizospheric soils collected from various locations of Kanpur region, India. These rhizobacterial isolates were characterized biochemically and screened for their PGP activities *in-vitro*. They were tested isolates for their beneficial trait's ability to production IAA production, and production of other plant growth promoting substances.

Vejan et al. (2016) in his review mentioned the gap (mechanism of PGPR for the plant growth and the role of PGPR as biofertilizer) and summarized the mechanism of PGPR as a bio-fertilizer for agriculture sustainability.

Adnan et al. (2016) isolated 22 PGPR bacterial isolates from Rice rhizospheric soil samples from Surat region of Gujarat, India. They primarily screened these strains for plant growth promoting activities such as siderophore production, phosphate solubilization, IAA production, and HCN production as well as for protease and chitinase activity. In his study, it was found that 10 isolates showed siderophore, 6 isolates in case of p-solubilization, 13 isolates in case of IAA production whereas 4 isolates in case of HCN production were showed positive results.

Modi et al. (2017) isolated 6 strains of *Pseudomonas*, 4 strains of *Azotobacter* and 2 strain of *Bacillus* from Rice rhizospheric soil samples from different villages of a Bardoli, Gujarat, India. They primarily screened these strains for plant growth promoting activities such as IAA production, phosphate solubilization, siderophore production, nitrogen fixation and protease production.

Moustaine et al. (2017) isolated three different bacterial isolates and proceed with *in vitro* screening for plant growth promoting activities; phosphate solubilization, nitrogen fixation, indole acetic acid (IAA), ammonia production and antimicrobial enzymes (cellulose, chitinase and protease) activity. This experiment was conducted in the field of National Institute of Agronomic Research of Meknes, Morocco.

Odoh (2017) in his review aim at exploring how PGPR suppresses phytopathogens while aiding plant growth through biofertilization and phytostimulation and potential of its application and commercialization within the tropics.

Gunjal et al. (2019) evaluates paddy husk and press mud-based formulation of *Burkholderia gladioli* for the plant growth in maize, wheat, jowar, and bajra for plant growth promotion. The use of paddy husk and press mud based bioformulations of *Burkholderia gladioli* for plant growth promotion will be a new herald in blossoming of agriculture and soil biotechnology. This will be very eco-friendly, non-toxic, cheap, and also reduce the use of chemical fertilizers.

Research Gap Identification

A number of research groups have reported for the isolation of PGPR's from rhizospheric soil samples of tomato plants (*Solanum lycopersicum*), but there are few research literatures available on carrier based bioformulation. Also, a small amount of work has been done separately on bioformulation and biocontrol activities of these bacterial isolates, but in present investigation, I shall complete this research work jointly. Such carriers like cocopeat, mustard husk, chinaberry leaf powder (Drek tree), and press mud-based bioformulation have not been used earlier by the researcher in tomato crops. The present research, therefore, aims to isolate PGPR from tomato plant from the Solan district of Himachal Pradesh and characterize these bacterial isolates on the basis of their growth promotion and bio-control activities.

Objectives

1. Isolation, screening, and identification of plant growth promoting rhizobacteria associated with the rhizospheric soil of tomato from Solan district of Himachal Pradesh
2. Characterization of potential PGPR isolates for various PGP attributes *in-vitro* conditions
3. Biochemical characterization and molecular identification of best selected PGPR by 16s r-RNA technique
4. Evaluation the efficacy of best selected PGPR's isolates in net house and field conditions

Proposed Methodology

1. Isolation of PGPR's from rhizosphere of Tomato crop

1.1 Collection of rhizospheric soil samples

The isolation of PGPR's associated with the rhizospheric soil of Tomato plants (Solanum lycopersicum) will be carried out from different location of Solan district

[Kandaghat (1,425 m), Nauni (1,275 m), Basal (1,502 m), and Jaunaji (1,502 m)] of Himachal Pradesh. Soil samples will be collected at a depth of 5-10 cm (Modi, Patel & Parmar, 2017). All the rhizospheric soil samples will be collected in clean and sterilized polythene bags or samples bags and stored in refrigerator for further study (Singh & Lal, 2016).

1.2 Isolation of PGPR

Isolation of microbes will be performed by serial dilution on Kings' B agar and Nutrient agar medium. Ten grams of fresh soil transferred in 90 ml of sterilized distilled water and mixed properly. All the soil samples are then serially diluted in the dilution range of 10-1 to 10-8 (Tsegaye et al., 2019). The soil sample (0.1 ml each) from each dilution mount on sterilized petriplates containing solidified media of Nutrient agar, and Kings' B agar media by spread plate and pour plate methods. Incubated the plates at 28 ± 2 ℃ for 24 hours (Singh & Lal, 2016).

2. Purification and morphological identification of PGPR isolates

Isolated rhizobacterial isolates will be identified on the basis of gram staining and morphological characteristics (colony shape, size, margin, opaque and pigmentation) according to the Bergey's manual of determinative bacteriology (Geetha et al., 2014). Isolated colonies of rhizobacterial isolates will be randomly selected and further purified by streaking (Tsegaye et al., 2019).

3. Characterization of selected isolates for various PGP attributes

3.1 Growth promoting activities by the isolates

a. Phosphate solubilization- The culture of bacterial isolates will be spot inoculated on the center of petriplates of Pikovskaya's agar medium and incubated in an incubator at 28 ± 2 ºC for 5-7 days (Kumar et al., 2021).

Observation- Presence of halozone around the colony shows the positive phosphate solubilization activity (Singh & Lal, 2016).

b. Production of Ammonia

Bacterial isolates will be tested for the production of ammonia in peptone water. Freshly grown culture will be inoculated in 10 ml peptone water in each tube an

inoculated for 48-72 hours at 36 ºC. Nessler's reagent (0.5 ml) will be added in each tube (Tsegaye et al., 2019).

Observation- Development of yellow to brown color are a positive test for ammonia production (Singh & Lal, 2016).

c. Production of Indole Acetic Acid (IAA)

IAA production was described by Brick et al. in 1991. Bacterial cultures will be grown on Luria Bertani cultures will be grown on Luria Bertani (LB) broth amended with 100 mg/l tryptophan as the precursor of IAA and incubated in a shaker at 250 rpm at 30 ºC for 3 to 5 days (Geetha et al., 2014). Fully grown cultures were centrifuged at 10,000 rpm for 10 min. 2 ml of supernatant will be mixed with 4 ml of the Salkowski reagent (Gusmiaty et al., 2019).

Observation- Appearance of pink color in test tubes will be indicating a positive result for IAA production (Chakra, Kumar & Swamy, 2019).

d. Production of organic acid

The bacterial organic acid production test will be conducted by inoculating test bacterial culture in minimal salt medium (MM9 broth) for 2 to 3 days at 30 ℃.

Observation- The appearance of pink color in the medium indicates organic acid formation using methyl red as an indicator (Tsegaye et al., 2019).

e. Test of Gibberellin content

Testing of gibberellin is measured by using the standard method to borrow isolates will be grown on nutrient broth medium and incubated at room temperature for 7 days. After that centrifuged for 10 minutes at a speed of 8000 rpm. The culture will be put into a 15 ml reaction tube and add 2 ml of zinc acetate solution. Subsequently, a 2 ml potassium ferrocyanide solution will be added and centrifuged for 10 min at 8000 rpm. A total of 5 ml supernatant will be added 5 ml of 30 % hydrochloric acid and incubated at 27 ℃ for 75 minutes.

Observation: The measurement of absorbance used a spectrophotometer at 254 nm (Gusmiaty et al., 2019).

3.2 Screening bacterial isolates for hydrolytic enzyme production:

f. Protease production

The culture will be inoculated on skim milk agar plate and incubated for 2 days at 28 ºC. Proteolytic activities will be identified by clear zone formation around the bacterial growth (Tsegaye et al., 2019).

g. Cellulase production

Isolates will be screened for Cellulase activity by inoculating on Carboxymethyl cellulose (CMC) agar. Plates will be prepared and inoculated with test organism and incubated at 28 ± 2 ºC for 5 days. Bacterial growth surrounded by clear halos are considered as positive indication of Cellulase production (Tsegaye et al., 2019).

h. Lipase production

Bacteria will be grown on nutrient agar amended with olive oil. After 48 hours of incubation the agar medium is flooded with copper sulphate and kept for 10-15 minutes. Formation of greenish blue color zones around the colony indicated the production of lipase (Geetha et al., 2014).

i. Production of amylase (Starch hydrolysis)

The bacterial isolates will be spot inoculated on starch agar (Beef extract 3.0, peptone 5.0, soluble starch 2.0, Agar 15.0, Distilled water 1 liter) medium plates and incubated at 30 °C for 48 hours. At the end of the incubation period, the plates were flooded with iodine solution, kept for a minute, and then poured off. Iodine reacts with starch to form a blue color compound. This blue color fades rapidly. Hence the colorless zone surrounding colonies indicates the production of amylase (Tsegaye et al., 2019).

3.3 Biocontrol activities of bacterial isolates

j. HCN Production

All the isolates will be screened out for the formation of hydrogen cyanide. Cultures will be streaked on prepared plates of nutrient agar medium amended with glycine (1.4 g/l). Whatman No. 1 filter paper strips will be soaked in 0.5 % picric acid followed by 2 % sodium carbonate and will be placed in the lid of each petriplates (Singh & Lal, 2016). Plates will be sealed with parafilm and were incubated at 28 ºC for 4-7 days.

Observation- The appearance of an orange or brown color indicates the potential result of the production of HCN (Singh et al., 2017).

k. Siderophore Production

Siderophore production will be detected by the method of Schwyn and Neilands using blue agar plates containing the dye chrom azurol S (CAS).

Observation- The colony showing orange/clear zones are considered as siderophore producing microbes (Rana et al., 2011).

l. Antifungal activity

The bacterial isolates tested for their antifungal activity will be grown in the respective broth media for 24 to 48 hours. A dual culture technique using PDA medium will be used for the testing of antifungal activity, PDA plates will be prepared and after media solidification 6 mm well are punched into the agar medium and filled with 150 µl of bacterial culture, agar plates (Meena, Gupta & Datta, 2016). A small bit of fungal growth placed near the streak or well containing the bacterial supernatant or culture. The plates will be incubated for the period of 4 to 5 days at 28 ℃. The percentage growth inhibition will be calculated using the following calculation (Hadi et al., 2021):

$$\% \text{ inhibition} = \left[\frac{(C-T) \times 100}{C}\right]$$

4. Biochemical Characterization of potential PGPR bacterial isolates

m. Oxidase test

Grow a fresh culture (24 hours) of bacteria. Add 2 to 3 drops of alpha-naphthol reagent directly to suspect colonies on agar plate. Observe color changes within 10 seconds. Appearance of deep purple-blue color indicates oxidase production within 5-10 seconds, and a negative reaction by absence of coloration or by coloration later than 60 seconds (Singh et al., 2017).

n. Voges-Proskauer test

Inoculum taken from a 24-hour old pure culture, lightly inoculate the medium. Incubate aerobically at 37 ℃ for 24 hours. After 24 hours of inoculation, aliquot 2 ml of the broth to a clean test tube. Add 6 drops of 5 % alpha-naphthol and mix well to

aerate. Add 2 drops of 40 % potassium hydroxide and mix well to aerate. Observe for a pink-red color at the surface within 30 min (McDevitt, 2009).

o. Catalase test

Pour 1-2 ml of hydrogen peroxide solution into a test tube. Using a sterile wooden stick or a glass rod, take several colonies of the 24 hours test organism and immerse in the hydrogen peroxide solution. Observe for immediate bubbling (Ahad et al., 2014).

p. Indole test

Take a sterilized test tubes containing 4 ml of tryptophan broth. Inoculate the tube aseptically by taking the growth from 18 to 24 hours culture. Incubate the tubes at 37 ℃ for 24 to 48 hours. Add 0.5 ml of Kovac's reagent to the broth culture. The formation of pink-red coloration (cherry red ring) in the reagent at the point of contact between the reagent and the medium indicates a positive result (MacWilliams, 2012).

5. Molecular identification of best selected PGPR bacterial isolates by 16s r-RNA amplification and sequencing

q. Genomic DNA isolation

Genomic DNA will be extracted according to the standard procedure. The 16s r-RNA of the strains amplified using the 16s r-RNA primers, fD1 (5'-GAGTTTGATCCTGGCTCAG-3') and Rp2 (5'-ACGGCTACCTTGTTACGACTT-3'). PCR products purified using QIA quick PCR purification kit. The purified DNA fragments will be sequenced using sequencer model ABI 3100 sequencer according to the protocol provided by the manufacturer (ABI PRISM 3100 Genetic Analyzer User's Manual) (Ahad et al., 2014).

r. Phylogenetic analysis

16s r-RNA sequence analysis performed with the aid of molecular evolutionary genetic analysis by using MEGA6 software package neighbor-joining method. For the phylogenetic trees, only sequences from the type strains whose names have been validly published considered (Sukweenadhi et al., 2019).

6. Biocompatibility of the selected isolates:

Biocompatibility of selected isolates will be studied by dual plate assay method on nutrient media. In order to prepare a consortium, it is essential that all microbes present in a consortium should be biocompatible. Biocompatibility among selected isolates will be determined by streaking one bacterial isolate across the middle of the nutrient agar plate. Other isolates will be streaked perpendicular to the above isolate and incubated (30 ℃, 48 hours). Zone of inhibition of growth at the junction of cultures will be noted (Hadi et al., 2021).

7. Pot experiment in net house conditions

Pot experiment will be conducted under the net house conditions. Plastic pots having 10 cm diameter X 10 cm deep will be used for this experiment containing 1 kg of sterilized soil. Fresh culture of each isolate will be used for each treatment (Sezen et al., 2016). All seeds will be sown in each pot containing 1 kg soil per pot which will be thinned to one plant after 15 days of germination. Pots will be placed in the net house under ambient light and temperature. The inoculum for the pot trials will be prepared by culturing the selected bacterial strains on nutrient agar. A single colony will be transferred to 250 ml flasks containing nutrient broth and grown aerobically in flasks on a rotating shaker (95 rpm) for 24 hours at 27 ºC (Meena, Gupta & Datta, 2016). After 24 hours the bacterial isolates will be transferred to the carrier (like cocopeat, mustard husk, chinaberry leaf powder (Drek tree), mud-based bioformulation). 1 ml of log culture (10^6 cells) of each bacterial isolates will be transferred as inoculum in the corresponding treatments. Treated and non-treated pots will be irrigated with sterilized water daily. After every 15 days interval 10 ml of microorganism inoculum will be inoculated in the corresponding pot as booster dose. At maturity stage and data regarding yield and yield contributing parameters will be collected and analyzed statistically (Dasgupta et al., 2015).

Net House Experiment

- Treatment-12
- Replication-3
- Statistical design-CRD

Parameters studied

- % Seed germination
- Plant height
- Number of leaves/branches
- Chlorophyll contents of leaves
- Total yield

8. Field Experiment

Field experiment will be conducted to further confirm the efficacy of selected bacterial strains to improve growth and yield of tomato under certain environmental conditions (Dasgupta et al., 2015). The selected PGPR isolates will be tested alone as well as in combination under field conditions. All the agronomic practices will be same as used in pot trial. At maturity, the crop will be harvested and data about growth and yield parameters will be recorded (Jarak et al., 2012).

Field Trial

- Treatment-12
- Replication-3
- Statistical design-RBD

Parameters

- % Seed germination
- Plant height
- Number of leaves
- Chlorophyll contents
- Total yield
- NPK of soil before trial and after trial
- Soil pH before and after trial
- Soil moisture before and after trial
- Total carbon before and after trial

Thesis Outline

Chapter 1	**Introduction**	This chapter gives the background of the research topic.
Chapter 2	**Literature Review, Research Gap Identification and Objectives**	In this chapter, the major studies that has been published on research topics and the various methodologies used has been summarized. Differences have been drawn from these studies and an explanation of how your research paper contributes to the literature. Research objectives have been decided on the basis of research gap.
Chapter 3	**Methodology**	In this chapter, complete details of all research methods, procedure, and techniques used to identify the information has been provided.
Chapter 4	**Result and Discussion**	The results of the research work are shown in this chapter.
Chapter 5	**Summary and Conclusion**	In this chapter, the summary of the results of research work and the scopes of the further research has been provided.
Chapter 6	**References**	References are provided in Harvard referencing system.

References

Adnan, M., Patel, M., Reddy, M. N., Khan, S., Alshammari, E., Abdelkareem, A. M. & Hadi, S. (2016) Isolation and characterization of effective and efficient plant growth-promoting rhizobacteria from rice rhizosphere of diverse paddy fields of Indian soil. *ARPN Journal of agricultural and biological science*. 11 (9), 373-379. Available from: http://www.arpnjournals.org/jabs/research_papers/rp_2016/jabs_0916_823.pdf [Accessed 12 February 2021].

Ahad, A., Akhtar, M. N., Vasmatkar, P. & Baral, P. (2014) Biochemical characterization and Molecular fingerprinting of plant growth promoting rhizobacteria. *International Journal of Agriculture, Environment and Biotechnology*. 7 (3), 491-498. Available from: file:///C:/Users/91701/Downloads/PRPP.IJAEB.pdf [Accessed 09 March 2020].

Apastambh, A. R., Tanveer, K. & Baig, M. M. V. (2016) Isolation and characterization of plant growth promoting rhizobacteria from banana rhizosphere. *International Journal of Current Microbiology and Applied Sciences.* 5 (2), 59-65. Available from: file:///C:/Users/91701/Downloads/A.R.Apastambh,%20et%20al.pdf [Accessed 24 June 2021].

Arora, N. K., Khare, E. & Maheshwari, D. K. (2010) Plant growth promoting rhizobacteria: constraints in bioformulation, commercialization, and future strategies. In: Maheshwari, D. (ed.) *Plant growth and health promoting bacteria, Springer*. Berlin, Heidelberg, Springer, pp. 97-116. Available from: https://link.springer.com/chapter/10.1007/978-3-642-13612-2_5 [Accessed 20 February 2021].

Arora, N. K., Tiwari, S. & Singh, R. (2014) Comparative study of different carriers inoculated with nodule forming and free-living plant growth promoting bacteria suitable for sustainable agriculture. *Journal of Plant Pathology and Microbiology*. 5 (2), 229. Available from: https://www.longdom.org/open-access/comparative-study-of-different-carriers-inoculated-2157-7471.1000229.pdf [Accessed 11 August 2020].

Bauchet, G. & Causse, M. (2012) Genetic diversity in tomato (*Solanum lycopersicum*) and its wild relatives. In: Caliskan, M. (ed.) *Genetic diversity in plants*. Rijeka, Croatia, IntechOpen, pp.134-162. Available from: https://www.intechopen.com/books/2252 [Accessed 6th December 2019].

Bhatt, M. K., Labanya, R. & Joshi, H. C. (2019) Influence of long-term chemical fertilizers and organic manures on soil fertility-A review. *Universal Journal of Agricultural*

Research. 7 (5), 177-188. Available from: https://www.hrpub.org/download/20190930/UJAR2-10413436.pdf [Accessed 19 March 2022].

Burnett, S. E., Mattson, N. S. & Williams, K. A. (2016) Substrates and fertilizers for organic container production of herbs, vegetables, and herbaceous ornamental plants grown in greenhouses in the United States. *Scientia Horticulturae*. 208, 111-119. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0304423816300024?via%3Dihub [Accessed 19 March 2022].

Chakra, P. S., Kumar, P. V. & Swamy, C. T. (2019) Isolation and biochemical characterization of plant growth promoting bacteria from a maize crop field. *International Journal of Current Microbiology and Applied Sciences.* 8 (4), 1415-1422. Available from: file:///C:/Users/91701/Downloads/Prashantkumar%20S.%20Chakra,%20et%20al.pdf [Accessed 26 January 2022].

Chakraborty, A., Mala, R. H., Rajgopal, R., Jain, M., Yadav, R., Siddalingeshwara, K.G. & Pramod, T. (2014) Isolation and characterization of potential plant growth promoting rhizobacteria from non-rhizospheric soil. *International Journal of Current Microbiology and Applied Sciences*. 3 (4), 432-438. Available from: https://www.ijcmas.com/vol-3-4/Arindam%20Chakraborty,%20et%20al.pdf [Accessed 11 January 2022].

Dasgupta, D., Ghati, A., Sarkar, A., Sengupta, C. & Paul, G. (2015) Application of plant growth promoting rhizobacteria (PGPR) isolated from the rhizosphere of Sesbania bispinosa on the growth of chickpea (Cicer arietinum L.). *International Journal of Current Microbiology and Applied Sciences*. 4 (5), 1033-1042. Available from: https://www.ijcmas.com/vol-4-5/Dipanwita%20Dasgupta,%20et%20al.pdf [Accessed 04 December 2021].

Di Benedetto, N. A., Corbo, M. R., Campaniello, D., Cataldi, M. P., Bevilacqua, A., Sinigaglia, M. & Flagella, Z. (2017) The role of plant growth promoting bacteria in improving nitrogen use efficiency for sustainable crop production: a focus on wheat. *AIMS microbiology*. 3 (3), 413-434. Available from: http://www.aimspress.com/article/10.3934/microbiol.2017.3.413 [Accessed 12 March 2022].

Gatahi, D. M. (2020) Challenges and opportunities in tomato production chain and sustainable standards. *International Journal of Horticultural Science and Technology*. 7 (3), 235-262. Available from: https://ijhst.ut.ac.ir/article_77127_88fbcd2aa6d13a3fe5a7ee57d521a88a.pdf [Accessed 17 May 2021].

Geetha, K., Venkatesham, E., Hindumathi, A. & Bhadraiah, B. (2014) Isolation, screening and characterization of plant growth promoting bacteria and their effect on Vigna Radita

(L.) R. Wilczek. *International Journal of Current Microbiololgy and Applied Sciences*. 3 (6), 799-899. Available from: https://www.ijcmas.com/vol-3-6/K.Geetha,%20et%20al.pdf [Accessed 24 August 2021].

Gunjal, A. B. & Kapadnis, B. P. (2019) Agroindustry By-Product Based Formulations of Burkholderia gladioli for Plant Growth. *Proceedings of the Indian National Science Academy*. 85 (3), 689-695. Available from: https://www.researchgate.net/publication/333451567_Agroindustry_ByProduct_Based_Formulations_of_Burkholderia_gladioli_for_Plant_Growth [Accessed 04 December 2021].

Gupta, G., Parihar, S. S., Ahirwar, N.K., Snehi, S. K. & Singh, V. (2015) Plant growth promoting rhizobacteria (PGPR): Current and future prospects for development of sustainable agriculture. *Journal of Microbial & Biochemical Technology*. 7 (2), 096-102. Available from: https://www.researchgate.net/publication/312317608_Plant_Growth_Promoting_Rhizobacteria_PGPR_Current_and_Future_Prospects_for_Development_of_Sustainable_Agriculture [Accessed 16 August 2020].

Gusmiaty., Restu, M., Bachtiar, B. & Larekeng, S. H. (2019) Gibberellin and IAA Production by Rhizobacteria from Various Private Forest. *In IOP Conference Series: Earth and Environmental Science*. 270 (1), 012018. Available form: https://iopscience.iop.org/article/10.1088/1755-1315/270/1/012018/pdf [Accessed 26 January 2022].

Hadi, A. E., Khalisha, A., Pambudi, A. & Effendi, Y. (2021) Potential of bacteria consortium as growth controller of pathogenic fungi Fusarium oxysporum F. sp. cubense (Foc). In *IOP Conference Series: Earth and Environmental Science*. 637 (1), 012029. Available from: https://iopscience.iop.org/article/10.1088/1755-1315/637/1/012029/pdf [Accessed 23 February 2021].

Hayat, R., Ahmed, I. & Sheirdil, R. A. (2012) An overview of plant growth promoting rhizobacteria (PGPR) for sustainable agriculture. In: Ashraf, M., Öztürk, M., Ahmad, M., Aksoy, A. (eds.) *Crop production for agricultural improvement: Springer*. Dordrecht, Springer, pp. 557-579. Available from: https://link.springer.com/chapter/10.1007/978-94-007-4116-4_22 [Accessed 04 December 2021].

Hayat, R., Ali, S., Amara, U., Khalid, R. & Ahmed, I. (2010) Soil beneficial bacteria and their role in plant growth promotion: a review. *Annals of microbiology*. 60 (4), 579-598. Available from: https://link.springer.com/article/10.1007/s13213-010-0117-1 [Accessed 19 January 2022].

Ibiene, A. A., Agogbua, J. U., Okonko, I. O. & Nwachi, G. N. (2012) Plant growth promoting rhizobacteria (PGPR) as biofertilizer: Effect on growth of Lycopersicum esculentus. *Journal of American Science*. 8 (2), 318-324. Available from: https://www.researchgate.net/publication/283435523_Plant_growth_promoting_rhizobacteria_PGPR_as_bio-fertilizer_Effect_on_growth_of_Lycopersicum_esculentus [Accessed 04 March 2022].

Islam, S., Akanda, A. M., Prova, A., Islam, M. T. & Hossain, M. M. (2016) Isolation and identification of plant growth promoting rhizobacteria from cucumber rhizosphere and their effect on plant growth promotion and disease suppression. *Frontiers in microbiology*. 6 (1360), 1-12. Available from: file:///C:/Users/91701/Downloads/fmicb-06-01360.pdf [Accessed 26 January 2022].

Itelima, J. U., Bang, W. J., Onyimba, I. A., Sila, M. D. & Egbere, O. J. (2018) Bio-fertilizers as key player in enhancing soil fertility and crop productivity: a review. *Direct Research Journal of Agriculture and Food Science*. 6 (3), 73-83. Available from: https://directresearchpublisher.org/drjafs/files/2019/07/Itelima-et-al.pdf [Accessed 08 August 2021].

Jarak, M., Bjeli, D., Joscaron, D., Hajnal-Jafari, T. & Stamenov, D. (2012) Effects of plant growth promoting rhizobacteria on maize in greenhouse and field trial. *African Journal of Microbiology Research*. 6 (27), 5683-5690. Available from: https://academicjournals.org/journal/AJMR/article-full-text-pdf/AE145EE39861 [Accessed 19 November 2021].

Kalay, A. M., Kesaulya, H., Talahaturuson, A. & Osok, R. (2021) The properties of rhizobacteria from tomato rhizosphere as biocontrol and biofertilizer. *In IOP Conference Series: Earth and Environmental Science*, IOP Publishing. 883 (1), 012001. Available from: https://iopscience.iop.org/article/10.1088/1755-1315/883/1/012001/pdf [Accessed 09 September 2021].

Khan, M. S., Zaidi, A., Wani, P.A., Ahemad, M. & Oves, M. (2009) Functional diversity among plant growth-promoting rhizobacteria: current status. In: Khan, M., Zaidi, A. & Musarrat, J. (eds.) *Microbial strategies for crop improvement*. Berlin, Heidelberg, Springer, pp. 105-132. Available from: https://link.springer.com/chapter/10.1007/978-3-642-01979-1_6 [Accessed 14 October 2021].

Khoo, H. E., Prasad, K. N., Kong, K. W., Jiang, Y. & Ismail, A. (2011) Carotenoids and their isomers: color pigments in fruits and vegetables. *Molecules*. 16 (2), 1710-1738.

Available from: https://www.mdpi.com/1420-3049/16/2/1710/htm [Accessed 11 March 2022].

Kumar, V., Indu., Richa., Kumar, S. & Sehajpal, D. (2021) Isolation and Screening of Plant Growth Promoting Rhizobacteria from the Rhizospheric Soil of Wheat (*Triticum aestivum*) from Lower Western Himalayan Zone of Himachal Pradesh. *International Journal of Current Microbiology and Applied Sci*ences. 10 (11), 23-34. Available from: file:///C:/Users/91701/Downloads/Vijay%20Kumar,%20et%20al.pdf [Accessed 27 January 2022].

Kundan, R., Pant, G., Jadon, N. & Agrawal, P. K. (2015) Plant growth promoting rhizobacteria: mechanism and current prospective. *Journal of Fertilizers and Pesticides*. 6 (2) 1-9. Available from: https://www.longdom.org/open-access/plant-growth-promoting-rhizobacteria-mechanism-and-current-prospective-jbfbp-1000155.pdf [Accessed 18 December 2021].

Lugtenberg, B. & Kamilova, F. (2009) Plant-growth-promoting rhizobacteria. *Annual review of microbiology*. 63 (1), 541-556. Available from: https://www.annualreviews.org/doi/pdf/10.1146/annurev.micro.62.081307.162918#article-denial [Accessed 14 October 2021].

MacWilliams, M. P. (2012) Indole test protocol. *American Society for Microbiology*. Washington, pp. 1-9. Available from: https://asm.org/getattachment/200d3f34-c75e-4072-a7e6-df912c792f62/indole-test-protocol-3202.pdf [Accessed 10 March 2022].

McDevitt, S. (2009) Methyl red and Voges Proskauer test protocols. *American Society for Microbiology*, pp. 1-8. Available from: https://asm.org/getattachment/0c828061-9d6f-4ae7-aea3-66e1a8624aa0/Methyl-Red-and-Voges-Proskauer-Test-Protocols.pdf [Accessed 04 January 2022].

Meena, M. K., Gupta, S. & Datta, S. (2016) Antifungal potential of PGPR, their growth promoting activity on seed germination and seedling growth of winter wheat and genetic variabilities among bacterial isolates. *International Journal of Current Microbiology and Applied Sciences.* 5 (1), 235-243. Available from: file:///C:/Users/91701/Downloads/Manoj%20Kumar%20Meena,%20et%20al.pdf [Accessed 15 October 2021].

Modi, K., Patel, P. & Parmar, K. (2017) Isolation, screening and characterization of PGPR from rhizosphere of rice. *Indian Journal of Pure & Applied Biosciences.* 5 (3), 264-270. Available from: http://www.ijpab.com/form/2017%20Volume%205,%20issue%203/IJPAB-2017-5-3-_264-270.pdf [Accessed 26 January 2022].

Moustaine, M., Elkahkahi, R., Benbouazza, A., Benkirane, R. & Achbani, E. H. (2017) Effect of plant growth promoting rhizobacterial (PGPR) inoculation on growth in tomato (Solanum lycopersicum L.) and characterization for direct PGP abilities in Morocco. *International Journal of Environment, Agriculture and Biotechnology*. 2 (2), 590-596. Available from: https://ijeab.com/upload_document/issue_files/5%20IJEAB-FEB-2017-36Effect%20of%20plant%20growth%20promoting%20rhizobacterial%20(PGPR)%20inoculation%20on%20growth%20in%20tomato.pdf [Accessed 17 May 2021].

Nihorimbere, V., Ongena, M., Smargiassi, M. & Thonart, P. (2011) Beneficial effect of the rhizosphere microbial community for plant growth and health. *Biotechnology, Agronomy, Society and Environment.* 215 (2), 327-337. Available from: https://popups.uliege.be/1780-4507/index.php?id=7578 [Accessed 08 August 2021].

Nosheen, S., Ajmal, I. & Song, Y. (2021) Microbes as biofertilizers, a potential approach for sustainable crop production. *Sustainabi*lity. 13 (4:1868), 1-20. Available from: https://www.mdpi.com/2071-1050/13/4/1868/htm [Accessed 10 January 2022].

Noumavo, P. A., Agbodjato, N. A., Baba-Moussa, F., Adjanohoun, A. & Baba-Moussa, L. (2016) Plant growth promoting rhizobacteria: Beneficial effects for healthy and sustainable agriculture. *African Journal of Biotechnology*. 15 (27), 1452-1463. Available from: https://academicjournals.org/journal/AJB/article-full-text-pdf/45A4A0959423 [Accessed 21 April 2021].

Odoh, C. K. (2017) Plant growth promoting rhizobacteria (PGPR): a bioprotectant bioinoculant for sustainable agrobiology: A review. *International Journal of Advanced Research in Biological Sciences.* 4 (5), 123-142. Available from: https://ijarbs.com/pdfcopy/may2017/ijarbs14.pdf [Accessed 08 August 2021].

Pahalvi, H. N., Rafiya, L., Rashid, S., Nisar, B. & Kamili, A. N. (2021) Chemical fertilizers and their impact on soil health. In: Dar, G. H., Bhat, R. A., Mehmood, M.A. & Hakeem, K.R. (eds.) *Microbiota and Biofertilizers, Vol: 2 Ecofriendly tools for remediation of degraded soil environs*. Cham, Springer, pp. 1-20. Available from: https://link.springer.com/chapter/10.1007/978-3-030-61010-4_1 [Accessed 26 March 2021].

Pande, A. & Kulkarni. (2015) Isolation of plant growth promoting bacteria from wheat (Lok-1) rhizosphere. *International Journal of Science and Research*. 4 (6), 524-527. Available from: https://www.researchgate.net/publication/340460386_Isolation_of_Plant_Growth_Promoting_Bacteria_from_Wheat_Lok1_rhizosphere?channel=doi&linkId=5e8b378b92851c2f5283346a&showFulltext=true [Accessed 12 February 2022].

Pande, V. & Bisht, T. S. (2019) Integrated Use of Bioferilizer and Biopesticides in Crop Production. In: Kaushik, B. D., Kumar, D. & Shamim, Md. (eds.) *Biofertilizers and Biopesticides in Sustainable Agriculture*. CRC Press, pp. 319-336. Available from: https://books.google.co.in/books?hl=en&lr=&id=jAW5DwAAQBAJ&oi=fnd&pg=PA319&dq=Pande,+V.+%26+Bisht,+T.S.+(2019)+Integrated+Use+of+Bioferilizer+and+Biopesticides+in+Crop+Production.+In:+Kaushik,+B.+D.,+Kumar,+D.+%26+Shamim,+Md.+(eds.)+Biofertilizers+and+Biopesticides+in+Sustainable+Agriculture.+CRC+Press,+pp.+319336&ots=beDVXmZuLX&sig=OWaVBjHs4isz1gLN8P2xSvDLRes#v=onepage&q&f=false [Accessed 19 June 2021].

Philippot, L., Raaijmakers, J. M., Lemanceau, P. & Van Der Putten, W. H. (2013) Going back to the roots: the microbial ecology of the rhizosphere. *Nature Reviews Microbiology*. 11 (11), 789-799. Available from: https://slunik.slu.se/kursfiler/BI1095/30237.1314/Philippot_NRM_2013.pdf [Accessed 08 August 2021].

Rana, A., Saharan, B., Joshi, M., Prasanna, R., Kumar, K. & Nain, L. (2011) Identification of multi-trait PGPR isolates and evaluating their potential as inoculants for wheat. *Annals of microbiology*. 61 (4), 893-900. Available from: https://link.springer.com/article/10.1007/s13213-011-0211-z [Accessed 20 January 2022].

Sezen, A., Ozdal, M., Koc, K. & Algur, O. F. (2016) Isolation and characterization of plant growth promoting rhizobacteria (PGPR) and their effects on improving growth of wheat. *Journal of Applied Biological Sciences*. 10 (1), 41-46. Available from: https://jabsonline.org/index.php/jabs/article/view/485/487 [Accessed 15 May 2021].

Singh, R., Pandey, D. K., Kumar, A. & Singh, M. (2017) PGPR isolates from the rhizosphere of vegetable crop Momordica charantia: characterization and application as biofertilizer. *International Journal of Current Microbiology and Applied Sciences*. 6 (3), 1789-1802. Available from: https://www.ijcmas.com/6-3-2017/Ritu%20Singh,%20et%20al.pdf [Accessed 20 September 2021].

Singh, Y. & Lal, N. (2016) Isolation and Characterization of from Wheat (*Triticum aestivum*) Rhizosphere and Their Plant Growth PGPR Promoting Traits in Vitro. *Indian Journal of Biology.* 6 (2), 139-144. Available from: https://www.frontiersin.org/articles/10.3389/fmicb.2015.00198/full [Accessed 08 August 2021].

Sukweenadhi, J., Purwanto, M. G. M., Hardjo, P.H., Kurniawan, G. & Artadana, I. B. M. (2019) Isolation and in vitro screening of plant growth promoting rhizobacteria from Barak Cenana red rice. In: Mahat, A. N., Wahab, Ab. R., Huyop, Z. F., Keyon, S. A. A., Attan,

B. N., Chandren, S. & Gunam, B. W. I. (eds.) AIP 2019: *Biosciences and Medical Engineering (ICBME2019)*: AIP Conference Proceedings. AIP 2019, 11–12 April 2019, Bali, Indonesia. 2155 (1), 020037. Available from: file:///C:/Users/91701/Downloads/4.AIPProceedingsIsolationofRhizobacteriafromRedRiceBarakCenana.pdf [Accessed 19 January 2022].

Tiwari, A., Devi, S., Kumar, S. N. & Sharma, S. (2016) Isolation, screening and characterization of PGPR isolated from rhizospheric soils of Pigeonpea. *Research Journal of Biotechnology*. 11 (3), 108-113. Available from: https://www.researchgate.net/publication/298703911_Isolation_screening_and_characterization_of_PGPR_isolated_from_rhizospheric_soils_of_Pigeonpea [Accessed 25 January 2022].

Tsegaye, Z., Gizaw, B., Tefera, G., Feleke, A., Chaniyalew, S., Alemu, T. & Assefa, F. (2019) Isolation and biochemical characterization of plant growth promoting (PGP) bacteria colonizing the rhizosphere of Tef crop during the seedling stage. *Journal of Plant Science and Phytopathology*. 14, 013-027. Available from: https://www.heighpubs.org/jpsp/jpsp-aid1027.php [Accessed 17 March 2021].

Vejan, P., Abdullah, R., Khadiran, T., Ismail, S. & Boyce, A. N. (2016) Role of plant growth promoting rhizobacteria in agricultural sustainability—a review. *Molecules*. 21 (5), 573. Available from: https://www.mdpi.com/1420-3049/21/5/573/htm [Accessed 10 January 2022].

Yahya, M., Islam, E., Rasul, M., Farooq, I., Mahreen, N., Tawab, A., Irfan, M., Rajput, L., Amin, I. & Yasmin, S. (2021) Differential Root Exudation and Architecture for Improved Growth of Wheat Mediated by Phosphate Solubilizing Bacteria. *Frontiers in microbiology*. 12 (744094), 1-23. Available from: https://www.frontiersin.org/articles/10.3389/fmicb.2021.744094/full [Accessed 27 February 2022].

CERTIFICATE

(SYNOPSIS APPROVAL CERTIFICATE)

This is to certify that the Synopsis/ Revised Synopsis for Ph.D. Thesis titled, "Studies the Efficacy of Plant Growth Promoting Rhizobacteria on Tomato (*Solanum lycopersicum*) Growing in Lower-Western Himalayan Zone of Himachal Pradesh", submitted by Ms. Indu (H15123) to the Career Point University, Hamirpur (H.P.), India in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY in the Division of Microbiology, School of Pharmaceutical and Health Sciences has been approved by the Research Advisory Committee (RAC) after an Oral Examination of the student on dated 28-01-2022.

Dr. Vijay Kumar,
Assistant Professor
Division of Microbiology
(Supervisor)

Research Advisory Committee

Dr. Ajay Sharma,
Associate Professor,
Department of Chemistry
(RAC Member)

Dr. Shailja Kumari
Assistant Professor,
Division of Zoology
(RAC Member)

Dr. Shikha Kumari
Assistant Professor,
Division of Microbiology
(RAC Member)

Dr. Vijay Kumar
Assistant Professor,
Division of Microbiology
HoD
(Head)

Dr. Kuldeep Kumar
Associate professor,
Department of Chemistry
(Dean/Assoc Dean R & D)